The Use of Periphyton as Indicators of Water Quality in Segments of the Upper Verde River, Yavapai County, and Oak Creek, Coconino County, Arizona.

Eisenhower Consortium Grant EC-346
USDA RMF & RES RM-80-103-GR

Technical Completion Report

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INTRODUCTION

This report documents work performed in accordance with the provisions of a grant awarded in March 1980. The major part of the field work was done in the summer of 1980 with the remainder being completed during 1981. Identification of the diatom specimens and all other analytical procedures were completed by February 1982. The original title of the study plan (submitted in accordance with the provisions of the grant) was "Quantifying Recreation and Acid Mine Spoil Impacts on Two Southwestern Streams." It is believed that the current title is a better indicator of the nature of the research and more adequately describes the work reported herein.

The purpose of the project was stated as:

1. to identify qualitative and quantitative differences in diatom assemblages resulting from recreational use and acidic mine spoil drainage in two specific stream segments

2. to determine the relationships between identifiable diatoms and other water quality indicators

3. to develop, insofar as possible, production function equations to express differences in water quality resulting from either recreational use or acid mine spoil damage.

Progress reports were submitted in July 1980 and July 1981. On 26 October 1981, an extension of the period of the agreement was granted from 31 December 1981 until 1 July 1982.

Scope

The Verde River begins in Chino Valley near Prescott, Yavapai County, Arizona and flows in a southerly direction for 125 miles until it joins the Salt River north of Phoenix, Arizona. Above the village of Camp Verde it is, itself, joined by three major tributary streams: Sycamore Creek, Oak Creek, and Beaver Creek. The Verde also receives small tributary flows from

numerous side canyons and from several rather inconsequential streams; among which is Bitter Creek (Figure 1), a small perennial stream which drains lands on the south side of the river below the abandoned smelter site located at Clarkdale, Yavapai County, Arizona. Bitter Creek is spring-fed.

One intent of this study was to document changes to the periphyton communities in the Verde River caused by the discharge of Bitter Creek and to determine if there was a way to quantify the particular impact of this stream on the Verde River System. For this reason, a major portion of the study centered on that reach of the river where Bitter Creek enters the Verde proper, above the communities of Cottonwood and Cornville. This study also continued the project described in Avery and Blinn (1981) which was designed to monitor the influence of intensive recreation activities on periphyton in the Slide Rock segment of Oak Creek. Slide Rock, located 6.5 miles north of Sedona, along US 89A in Coconino County, Arizona, is noteworthy as an intensely-used recreation area. The location of the Slide Rock portion of this study is shown in Figure 2.

Background

Because there is only a limited number of stream segments which offer Arizona residents both permanent water and convenient as well as outstanding recreational opportunities, such areas are well known; they are also heavily impacted during summer months. Oak Creek, between Flagstaff and Sedona, is one of these locations and the Slide Rock segment is of critical concern to Forest Service managers charged both with maintaining the quality of the aquatic resource and with upholding state water quality standards and/or federal Clean Water Act mandates. Another widespread concern for persons responsible for water quality

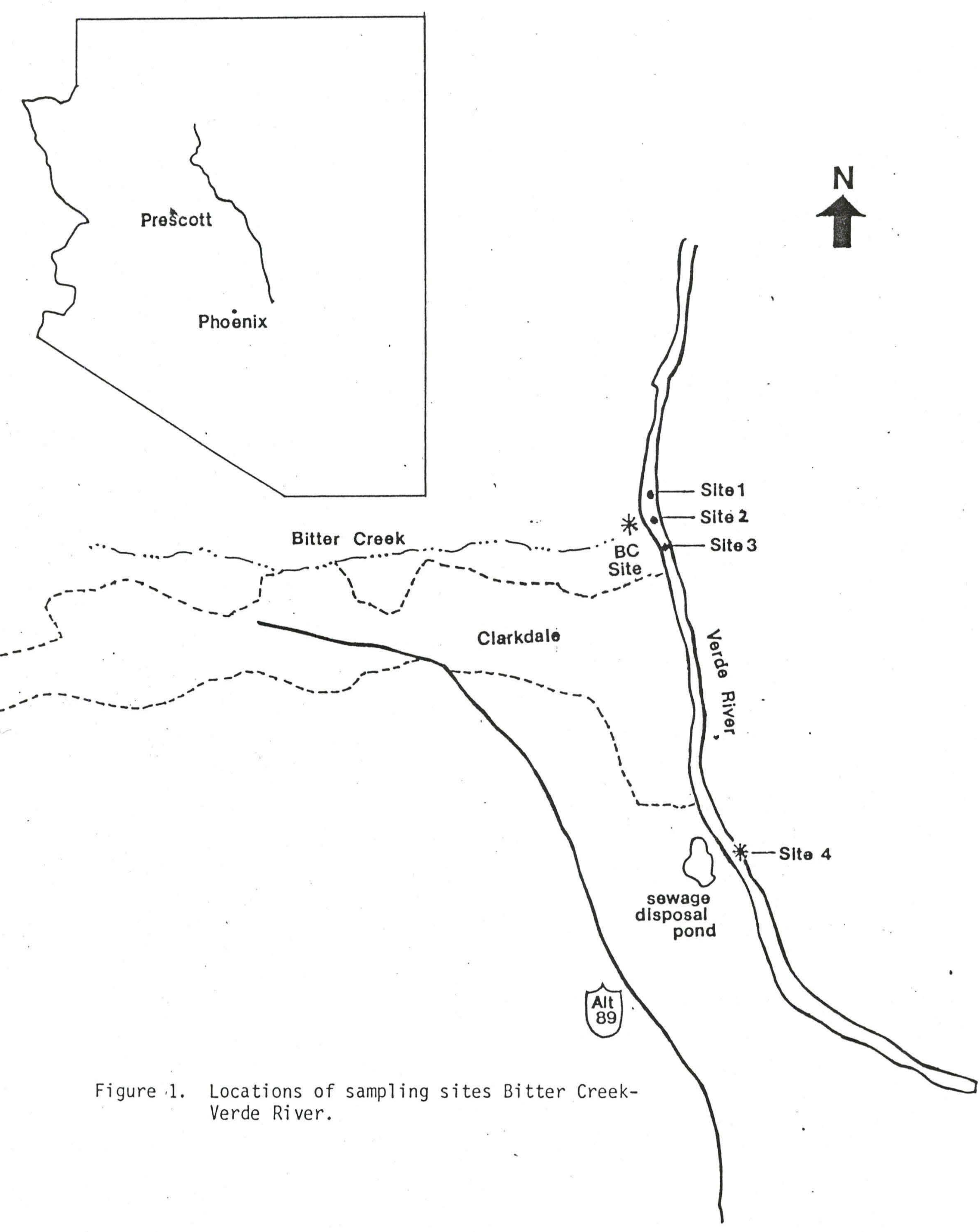

Figure 1. Locations of sampling sites Bitter Creek-Verde River.

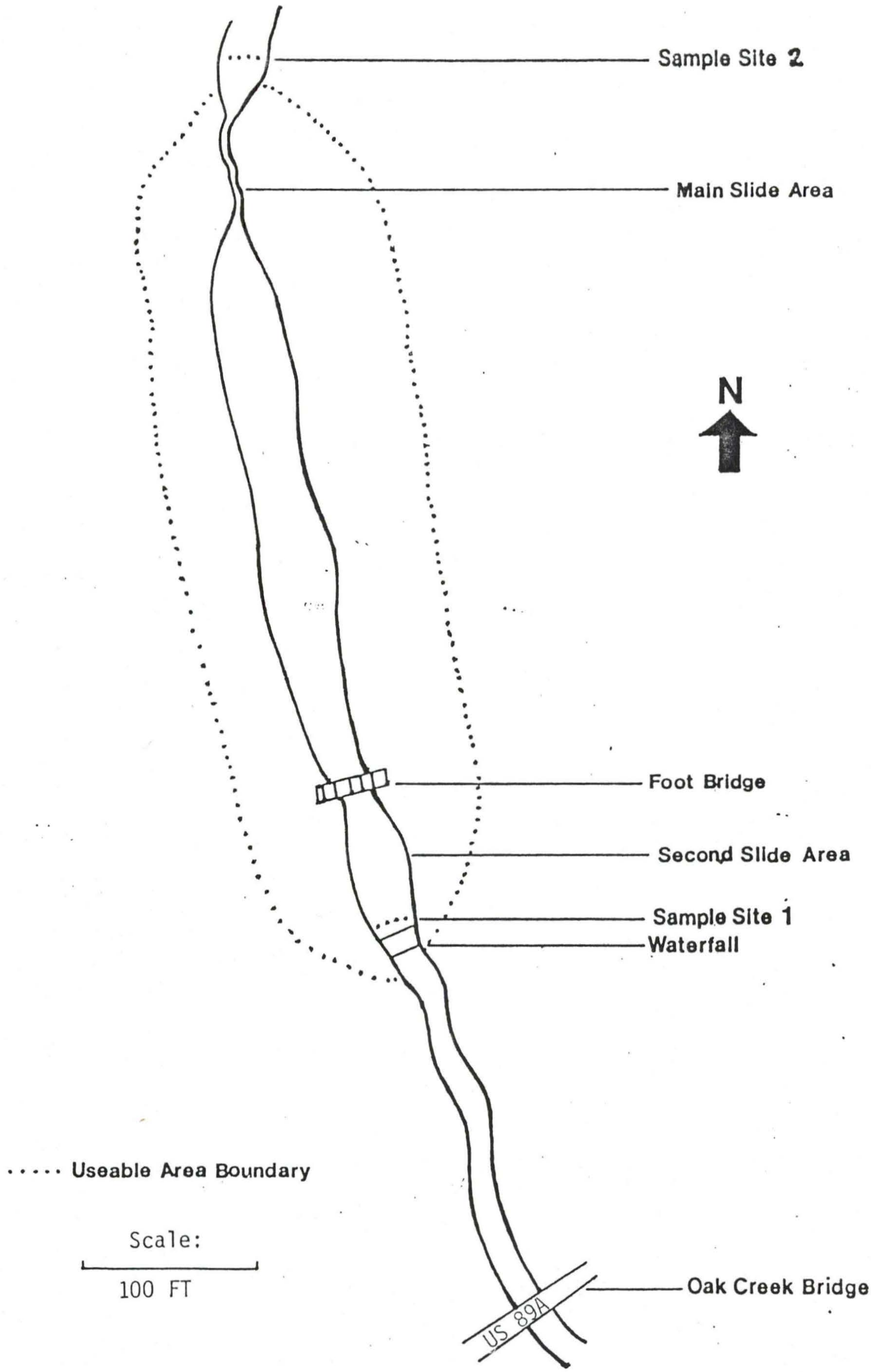

Figure 2. Locations of sampling sites Oak Creek-Slide Rock.

in Arizona is the biological impact of acidic mine spoils runoff especially since certain species of diatoms might be very sensitive to small amounts of heavy metals, and their disappearance could alter the productivity rates of the stream segment.

Because algae are primary producer organisms, and because the species composition and abundance of the algae components at a stream often reflect the integration of the chemical and physical parameters which ultimately determine the ecological nature of the waterway, they could conceivably serve as "biological integrators". Moreover, it appears that they respond to any environmental changes in an attenuated fashion and among the algae attached diatoms are noteworthy for their specificity to various chemical and physical factors. Therefore it was this class of organism which was evaluated to determine if in these two specific locations, it was usable as an indicator of the "quality" of these stream segments.

Diatoms as Indicators of Water Quality

There is no single quality index that designates such a ubiquitous commodity as water as being either "good" or "bad." Rather, the suitability of water for a designated use must be evaluated on a case-by-case basis and suitability is generally stated in terms of the water's chemical, physical, and biological characteristics. Agriculture, industry, recreation, and other human activities have determinable needs for water with different quality characteristics; it is quite to be expected, therefore, that simplifying the task of designating the suitability of natural waters for various uses is an on-going process.

While chemical and physical water quality descriptions are numerous and of recognized utility for various purposes, it also appears that living organisms can serve as a type of water quality descriptor. In point of fact, surveys of streams in order to cataloque their biological components are often included as part of general water quality assessment studies. But except for the widewpread use of (caged) trout as "water quality monitoring devices," there was, until recently, little information on the value of other classes of organisms as water quality indicators.

Recent work by phycologists has highlighted the value of certain diatoms as indicator organisms. Cairns published in the Proceedings of the National Academy of Sciences in 1972, his major report on the relationship between pollution of waters and changes in the composition of the aquatic producer organism complex. Work by Whitton (1970) at about the same time underscored the effect of heavy metals on fresh-water algae. Because periphytic algae are a very important component of desert and semi-desert aquatic systems and because in these regions with little terrestrial or riparian vegetation such forms are probably the principal carbon "fixers" of the ecosystems, any disturbance to this part of the producer component of the food chain is likely to have significant implications (Lampkin and Sommerfeld, 1981).

In their 1981 report Avery and Blinn reported that heavy recreation use of a stream segment did not appear to disrupt the periphytic community and they ascribed this observed condition to the (relative) infrequency of the impact and/or to its periodic nature which allowed for an almost daily "recovery stage."

This study was intended to extend the previous work through a consecutive year and to investigate the possibility of using diatoms which occur in the reach of the Verde River near the confluence of Bitter Creek as water quality indicator organisms.

METHODS

Site Descriptions

The two sites' locations are as follows:

Bitter Creek - Sec. 17, T16N, R3E

Slide Rock - Sec. 17, T18N, R8E

Slide Rock is located 21 miles south of Flagstaff, Arizona and 6.5 miles north of Sedona on U.S. Highway 89A. The recreation area is immediately north of the Oak Creek Bridge at an elevation of approximately 5,000 feet.

Oak Creek is a steep-walled canyon dissecting the southern margin of the Colorado Plateau. Its chasm begins approximately 13 miles south of Flagstaff and extends about another 12 miles southward where it merges with the eastern margin of the broad Verde River Valley. It continues another 25 miles through the Verde Valley until it joins the Verde River. Oak Creek is a permanent stream which is fed mainly by springs emanating from a fault zone, although in some places there are springs which are located at the base of the canyon walls in the colluvial material (Museum of Northern Arizona 1962). Oak Creek is gaged near its confluence with the Verde River at Page Springs where its flow has been recorded since 1941. This record shows a cumulative mean discharge of 92.6 cubic feet per second (cfs). Long-term mean monthly discharges at this site, for the months of May, June, July, and September are 34.3, 21, 24.4, and 38 cfs (Anderson and White 1978). Measured discharges immediately above Slide Rock on 1 July 1979, 1 August 1979, 17 August 1979, and 27 August 1979 were, respectively, 12.0, 13.1, 11.5, and 10.9 cfs (Avery and Blinn 1981).

Bitter Creek enters the Verde River approximatley 8 river miles below a USGS gaging station (#5040) which has long-term record of 209 cfs for its cumulative mean discharge. The long-term averages for May, June, July, and

August are 94.7, 74.4, 128, and 114 cfs. Bitter Creek is not gaged, but during several visits over the course of 15 months its flow varied from maximum estimation of 10 cfs to a minimum close to zero, but it did not appear to dry up completely. (One instantaneous discharge measurement on 17 June 1980 indicated a 1.6 cfs flow; a few hours later the Verde River was measured at 60.9 cfs.) One mile above its confluence with the Verde River, Bitter Creek branches into a south fork which is not affected by mining waste and into a north fork which is heavily-impacted by leachate from abandoned mining.

Data Collection

Sampling was conducted at Slide Rock at three locations (Figure 2). Site one (S_1) was located immediately downstream from the lowest "slide" area, just above the waterfall and above the highway bridge crossing. The second site (S_2) was located five hundred feet upstream of S_1, and above the main slide area, while the third site (S_3) was located about six hundred feet upstream of S_2 and well above the main slide area.

This sampling design allowed for the designation of the section between sites one and two as the "control reach." Samples from this section measured the effect of high recreation use on the aquatic resource: as many as 800 persons have been observed in the "slide" area which is about five hundred feet long and about one hundred fifty feet wide.

Sampling at the Bitter Creek location was more extended both in space and time. Site one (S_1) was about 15 m above the confluence of Bitter Creek and the Verde River, another site (S_2), about 10 m below the confluence, was used only occasionally for chemical sampling, site three (S_3) was about 150 m

below the confluence, and a fourth site (S_4), was about 1500 m downstream of the confluence and was almost adjacent to the Clarkdale Sewage Treatment Facility. Also, several sample collections were done about 25 m upstream in Bitter Creek itself: interestingly, diatom cells were only occasionally recovered from this site.

The sampling period extended from June 1980 into October 1980. Sample collection was irregular and the ultimate disposition of the sample material varied by date. Sample collection dates were 3 June, 10 July, and 17 September 1980 at Slide Rock. The sampling at the Bitter Creek-Verde locations was done on 28 May, 27 June, 30 July, 30 August, and 23 October 1980.

Field and Laboratory Procedures

At the Slide Rock location the three sampling sites were sampled for periphyton by removing a core of the bedrock according to the procedure outlined in Avery and Blinn 1981 and Hamala et al 1981. Because of the condition of the Verde River and the Bitter Creek stream beds, a more conventional technique of algae collection was able to be used. Thus, at these sites, eight precut 3x3 cm sandstone blocks were mounted on weighted concrete blocks and incubated at each of the four sites for about a month prior to the sampling data. On each sampling date samples of periphyton were collected and preserved in formalin for identification purposes; one was examined live for taxonomic purposes.

From these four sites 3 blocks which had been colonized by periphyton were removed, submerged in water indigenous to the site, and transported to a common site in the Verde River. On each sample date, at this "common" site, the three colonized squares were placed in especially constructed individual,

clear plastic circular chambers (Rogers et al. 1978). The samples were then immersed in the water collected with them from their respective "colonized" sites. Five μCi of Carbon-14 (^{14}C) were then introduced into each chamber, and the chambers sealed. This procedure allowed a determination of the rate of primary productivity attributable to each site on each date.

The circular chambers contained a battery-driven motor which provided, through a small fan, circulation which simulated the stream current. The chambers were submerged, all together, for 1 to 2 hours (from about 1100 hours to about 1300 hours) on the designated sampling dates in the Verde River at the "common" site. This procedure provided for water circulation under relatively natural conditions of temperature and light. Following the 1 to 2 hour incubation period, the labeled ^{14}C periphyton material was carefully removed from the 9 cm^2 squares and filtered through 0.45 μm Millipore membranes.

Labeled periphyton from each square was filtered separately. The periphyton samples were then placed in scintillation vials with 10 ml of Instal-gel (Packard) and analyzed on a Packard model 2425 liquid scintillation spectrometer. Primary production rates were calculated according to the procedures outlined in Standard Methods (1976).

The material collected from the various substrates, whether initially from the Slide Rock location or from the Bitter Creek location, was subjected to the following laboratory procedure for taxonomic enumeration of the diatom assemblage component of the total periphyton community:

> The samples were brought to 20 ml volume following the hydrogen peroxide-potassium dichromate procedure described by Van der Werff (1953). Appropriate dilutions were made to ease counting procedures for various samples depending on cell densities. Aliquots of "cleaned" diatom material were dried onto 18 mm circle coverslips and permanent slide preparations were made using Hyrax mounting medium. Cell density estimates and species identification were made with a Zeiss phrase contrast microscope using a 100x Neoflour objective.

Community structure at each sampling Slide Rock station was computed by means of a commonly-used similarity index (SIMI) for each sampling date. The index

$$\mathrm{SIMI} = \frac{\sum_{i=1}^{s} P_{ij}P_{in}}{\sqrt{\sum_{i=1}^{s} P_{ij}^2}\sqrt{\sum_{i=1}^{s} P_{in}^2}}$$

is described by Sullivan (1977) and was used by Tuchman and Blinn (1979) for diatom evaluations. In this formula, P_{ij} and P_{in} are the average relative abundances, expressed as a proportion of the individual samples for each date, of the i-th species and the j-th community and $\underline{s}$ is the total number of species counted. These relative values (SIMI's) can range from 0 to 1 where 1 would suggest an identical community structure. (It should be noted that no statistically significant differences can be calculated by means of this particular similarity index.)

At the Bitter Creek location, samples for Cu, Zn, and Fe analysis were collected in 125 ml polyethylene bottles on each sampling date, acidified with approximately 2 ml concentrated nitric acid to a pH of 2.0, and later analyzed by atomic absorbtion procedures.[1] Storage until analysis was at 2°C.

Identification of the collected periphyton was done under the direction of Dean W. Blinn at the Aquatic Biology Laboratory of Northern Arizona University. The mounted slides are a part of the permanent collection of this facility.

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[1]A Perkins-Elmer Atomic Absorbtion Spectrophotometer was used. All samples were run against samples of known concentrations and the appropriate absorbance reading was recorded. Any samples that were higher in concentration than the common standard were diluted to be within the range of the standards. The resulting concentrations were then multiplied by the appropriate dilution factors to obtain the actual concentration. This work was done in the laboratory at the School of Forestry and in a commercial analytical laboratory.

RESULTS

Periphyton

Slide Rock

In their 1981 report, Avery and Blinn reported that 168 samples were removed and identified at Slide Rock in the summer of 1979. During the course of this study 32 samples were removed from the three Slide Rock sites on 3 June, 10 July, and 17 September 1980. For each site, species identification procedures produced the following composite picture (Table 1).

The 1979 data were tabulated and presented in the 1981 report on page 36 and in Appendix 2. A comparison of the two data sets suggest that the present (1980) algal assemblages were quite similar to these noted a year earlier.

Table 2 lists the SIMI values for both 1979 and 1980 for the three segments of Slide Rock, S_1, to S_2; S_1 to S_3; and S_2 to S_3. Water temperature for days close to the 1980 sampling dates are presented in Table 3.

Bitter Creek

Identification of the diatoms from this location was made in accordance with the procedures described earlier. The species' "density estimates" are tabulated as raw data in Appendix 1 for the following collection dates and sites:

Date	Sites (Figure 1)
28 May 1980	Bitter Creek proper
27 June 1980	1
30 August 1980	2
23 October 1980	3
	4

The appendix contains appropriate identifiers for each column. The data are reported in terms of total numbers per cm^2 which is, more properly, a density value rather than a "count" value. No similarity indices were tabulated for the data from the Bitter Creek location.

Table 1.--Relative abundance of dominant diatom periphyton at 3 stations at Slide Rock, Arizona, 1980

Species	Site 1	Site 2	Site 3
		3 June 1980	
Achnanthes lanceolata	2.1	1.1	1.6
Achnanthes minutissima	14.3	21.2	19.4
Cocconeis placentula var. euglypta	31.0	24.2	25.3
Cymbella affinis	0.5	0.1	0.3
Epithemia sorex	0.0	0.0	0.4
Navicula cryptocephala var. veneta	4.4	9.2	7.1
Navicula miniscula	1.3	1.0	0.7
Nitzschia fonticola	41.2	38.1	37.3
Nitzschia frustulum	0.0	0.1	0.0
Nitzschia kutzingiana	3.4	2.2	4.8
		10 July 1980	
Achnanthes lanceolata	3.1	1.2	2.2
Achnanthes minutissima	26.9	18.8	22.9
Cocconeis placentula var. euglypta	36.4	38.6	39.2
Cymbella affinis	11.4	15.5	12.3
Epithemia sorex	0.2	0.4	0.1
Navicula cryptocephala var. veneta	9.4	5.2	4.4
Navicula miniscula	0.4	1.7	1.8
Nitzschia fonticola	5.1	7.8	10.2
Nitzschia frustulum	1.2	3.9	1.7
Nitzschia kutzingiana	0.1	0.0	0.0
		17 September 1980	
Achnanthes lanceolata	0.0	0.0	0.1
Achnanthes minutissima	5.5	1.2	3.9
Cocconeis placentula var. euglypta	1.5	0.5	2.2
Cymbella affinis	43.8	39.2	37.1
Epithemia sorex	39.1	49.0	38.2
Navicula cryptocephala var. veneta	0.2	0.1	0.9
Navicula miniscula	0.1	0.0	0.7
Nitzschia fonticola	0.1	1.2	1.9
Nitzschia frustulum	4.9	5.2	7.8
Nitzschia kutzingiana	0.2	1.1	0.9

Table 2.--Similarity values (SIMI) for periphyton communities for Site 1 (S_1), Site 2 (S_2), and Site 3 (S_3) at Slide Rock, Arizona, 1979 and 1980

Date	S_1-S_2	S_1-S_2	S_2-S_3
1980			
3 June	.829	.894	.911
10 July	.924	.945	.967
17 September	.891	.935	.854
1979			
14 June	.837	.901	.779
10 July	.388	.945	.370
10 September	.951	.753	.866

Table 3.--Water temperatures[2] for Slide Rock, Arizona, 1979 and 1980

Date			
3 June 1980	16.3°C	17 June 1979	14.5°C
10 July 1980	16.7°C	8 July 1979	15.5°C
17 September 1980	14.2°C	9 September 1979	14.5°C

[2]Measured at time of sample collection or (1979) reported as "average" daily water temperature.

Chemicals/Metals

The water samples were analyzed on 28 May, 27 June, 30 July, 30 August, and 23 October 1980 for iron and arsenic as well as for copper and zinc. The raw data are presented in Appendix 2. Because of the very low amounts of arsenic and zinc, they are disregarded in Summary Table 4.

Primary Productivity

Primary productivity for the Verde system periphyton is presented in Table 5 where the value reported is in milligrams of carbon-14 fixed per cm^2 of periphyton per hour.

ANALYSIS AND DISCUSSION

Diatom Densities

A considerable amount of information is available because of the large number of samples taken over the course of the Bitter Creek investigation. However, due to the lack of replication due to logistics, most types of statistical analyses are not possible.

Table 6 shows the total diatom densities and species by location and date. Location does not appear to influence total count. Sample dates 2 and 3 (27 June and 30 August 1980) had the greatest number of species and dates 2 and 4 (27 June and 23 October 1980) had the largest values for total count. (Since the Verde River flow did not vary appreciably over this time period, water temperature fluctuation may be an important driving mechanism: see Table 6a.)

Table 4.--Copper (Cu) and zinc (Zn) values for the Bitter Creek-Verde River system near Clarkdale, Arizona

Station		27 June 1980 Cu	Zn	30 July 1980 Cu	Zn	30 August 1980 Cu	Zn	23 October 1980 Cu	Zn
1	Above confluence in Verde River	BD	BD	BD	0.06	BD	0.07	BD	BD
2	Immediately below confluence	BD	0.83	BD	0.78	BD	0.41	BD	0.20
3	@150 meters downstream	BD	0.35	BD	0.19	BD	0.16	BD	0.18
4	Near Clarkdale treatment facility @1500 m downstream	BD	0.12	BD	0.09	BD	0.09	BD	0.14
BC	Bitter Creek proper	0.20	5.2	0.20	6.90	BD	0.75	BD	0.37

Table 5.--Primary productivity of periphyton in the

Bitter Creek-Verde River system near Clarkdale, Arizona

		(^{14}C in mg cm^{-2} hr^{-1})			
Station		27 June 1980	30 July 1980	30 August 1980	23 October 1980
1	Above confluence in Verde River	15.3 $mgcm^{-2}hr^{-1}$	11.5 $mgcm^{-2}hr^{-1}$	12.4 $mgcm^{-2}hr^{-1}$	7.1 $mgcm^{-2}hr^{-1}$
2	Immediately below confluence	7.4	6.5	2.5	1.5
3	@150 m downstream	10.7	8.0	3.8	3.7
4	Near Clarkdale treatment facility @ 1500 m	9.3	10.7	7.2	4.1
BC	Bitter Creek Proper	Negligible	Negligible	Negligible	Negligible

Table 6.--Total counts by location and sampling, Bitter Creek.

Date	Location	Total count	N of species
1	1	330,365	16
(28 May 1980)	3	-	
	4	286,121	18
2	1	497,250	17
(27 June 1980)	3	1,283,682	20
	4	1,745,333	23
3	1	176,444	19
(30 August 1980)	3	806,514	24
	4	1,422,671	24
4	1	1,277,184	15
(23 October 1980)	3	1,128,521	18
	4	804,426	24

Table 6a.--Discharge, temperature, and pH data, Verde River at Clarkdale, 1980

Daily average	28 May	27 June	30 August	23 October
discharge (cfs)	89	84	79	83
Temp. (^{o}C)	17.5 (BC=17.5)	25 (BC=25)	21 (BC=21)	1.7^{o}C (BC=18)
pH	8.4 (BC=6.7)	8.5 (BC=6.8)	7.5 (BC=6.8)	7.5 (BC=6.7)

Table 7 displays the analyses of variance of total count by locations and sampling dates. Because there were no replicates, the interaction term (date x location) was used for the error term, viz:

Source	DF
date	3
location (site)	2
date x location	5

Figure 3 shows the counts by location and date.

Species 14 (Epithema sorex) and 29 (Nitzschia dissipata) occurred in all samples. Table 8 shows the total counts for these two species by date and location. These data show the same pattern as do the data plotted in Figure 3 (total count data) but there is no pattern with respect to location. Species 2, 3, 7, 10, 23, 33, and 39 occurred in ten out of a possible eleven samples (Table 9). There were no patterns for counts of these species with respect to location.

Samples from locations 1A and 1B appear to be somewhat different for samples taken on 30 August and 23 October 1980. No statistical test is possible, however. Intuitively, the variability could be explained by sampling error.

Tables 10 and 11 describe counts for each date and location by species, and genus, as was done with total counts. There are some seasonal patterns, but no pattern appears with relation to location (site). It appears as though the population structure of the river's diatom community remains intact even under the influence of the Bitter Creek inflow.

The interaction between zinc concentration and primary productivity was significant ($r^2 = 0.24$), but the precision of estimates for the regression equation is low. The regression equation is:

Primary productivity =-1.254 + 7.144 (Zn concentration)

Table 7.--Analysis of variance

Source of variation	DF	F	Significance of F
Main effects	5	1.301	.390
Date	3	1.283	.376
Location	2	1.060	.413
Explained	5	1.301	.390
Residual	5		
Total	10		

11 cases were processed

0 cases (.0 pct) were missing.

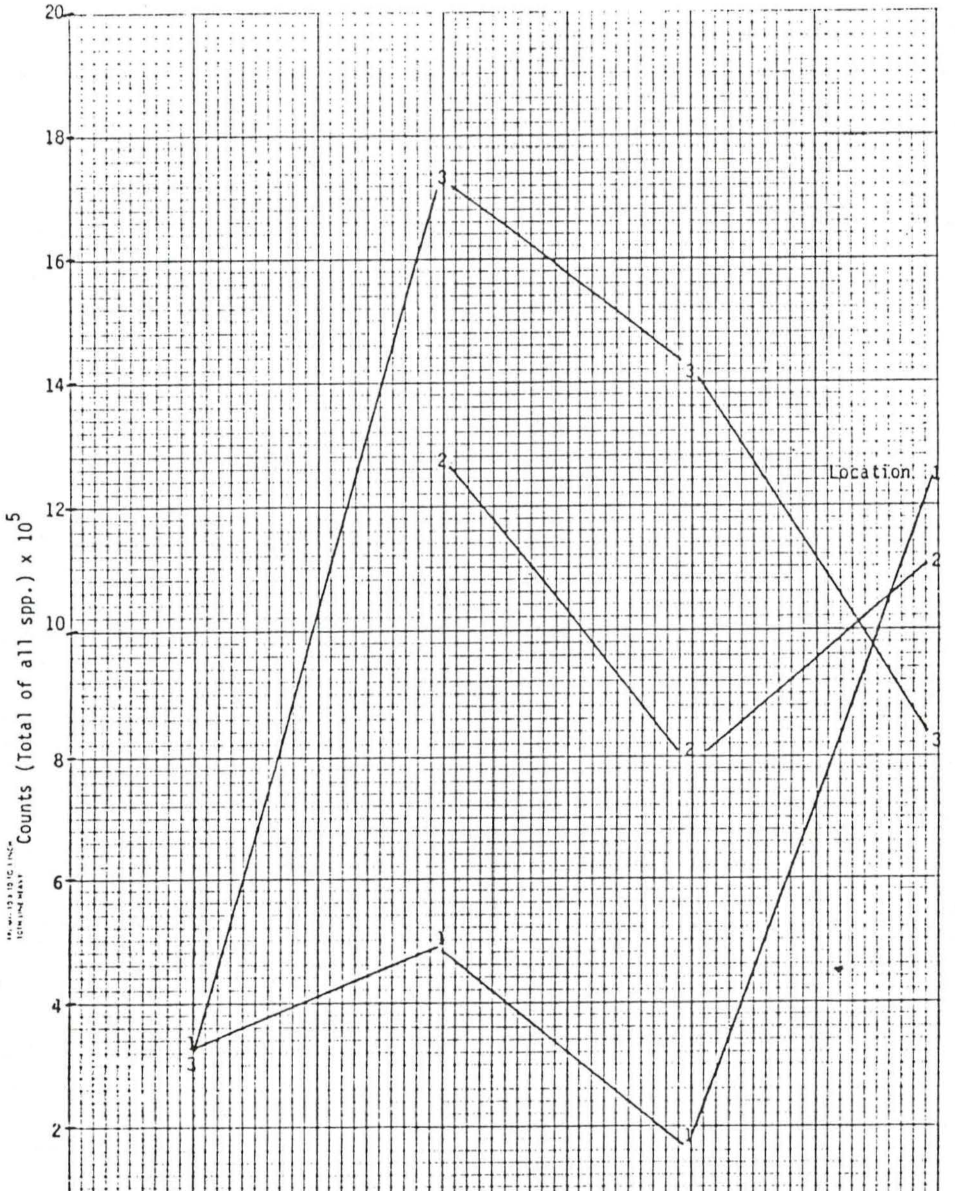

Figure 3.--Counts by location and date

Table 8.--Total counts of Epithema sorex (species 14) and Nitzchia dissipata (species 29) by date and location.

Date	Location	Species 14 count	Species 29 count
28 May 1980	1	3179	9537
	3		
	4	28612	41329
27 June 1980	1	77440	4076
	3	105971	11763
	4	190747	19074
30 August 1980	1	15896	7948
	3	22571	27182
	4	26482	6613
23 October 1980	1	184386	50862
	3	50548	25417
	4	46972	33380

Table 9.--Frequency of species occurrence

Species code[4]	Absolute freq.	Relative freq. (PCT)	Adjusted freq. (PCT)	Cum. Freq. (PCT)
1	7	3.2	3.2	3.2
2	10	4.6	4.6	7.8
3	3	1.4	1.4	9.2
4	7	3.2	3.2	12.4
6	9	4.1	4.1	16.5
7	10	4.6	4.6	21.1
8	6	2.8	2.8	23.9
9	4	1.8	1.8	25.7
10	10	4.6	4.6	30.3
11	5	2.3	2.3	32.6
12	5	2.3	2.3	34.9
13	8	3.7	3.7	38.5
14	11	5.0	5.0	43.6
15	7	3.2	3.2	46.8
17	1	.5	.5	47.2
18	2	.9	.9	48.2
19	1	.5	.5	48.6
20	1	.5	.5	49.1
21	2	.9	.9	50.0
22	9	4.1	4.1	54.1
23	10	4.6	4.6	58.7
24	6	2.8	2.8	61.5
25	5	2.3	2.3	63.8
26	1	.5	.5	64.2
27	1	.5	.5	64.7
28	3	1.4	1.4	66.1
29	11	5.0	5.0	71.1
30	7	3.2	3.2	74.3
31	9	4.1	4.1	78.4
32	4	1.8	1.8	80.3
33	10	4.6	4.6	84.9
34	10	4.6	4.6	89.4
35	6	2.8	2.8	92.2
36	1	.5	.5	92.7
37	10	4.6	4.6	97.2
38	6	2.8	2.8	100.0
Total	218	100.0	100.0	

[4]Coded list of species is located in Appendix 3.

Table 10. Diatom species[5] totals by location and date with descriptive statistics.

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE	N
FOR ENTIRE POPULATION			10137069.0000	40067.4664	87595.3738	************	(253)
DATE	1	05-28-80	647437.0000	14074.7174	37035.1370	************	(46)
LOCATION	1	ABOVE BITTER CR.	330365.0000	20647.8125	5978[illegible].7943	************	(16)
SPECIES	4		6358.0000	6358.0000	.0000	.0000	(1)
SPECIES	6		3179.0000	3179.0000	.0000	.0000	(1)
SPECIES	7		6358.0000	6358.0000	.0000	.0000	(1)
SPECIES	8		9524.0000	9524.0000	.0000	.0000	(1)
SPECIES	10		244544.0000	244544.0000	.0000	.0000	(1)
SPECIES	11		3179.0000	3179.0000	.0000	.0000	(1)
SPECIES	13		3179.0000	3179.0000	.0000	.0000	(1)
SPECIES	14		3179.0000	3179.0000	.0000	.0000	(1)
SPECIES	22		6358.0000	6358.0000	.0000	.0000	(1)
SPECIES	23		12717.0000	12717.0000	.0000	.0000	(1)
SPECIES	29		9537.0000	9537.0000	.0000	.0000	(1)
SPECIES	31		3179.0000	3179.0000	.0000	.0000	(1)
SPECIES	33		9537.0000	9537.0000	.0000	.0000	(1)
SPECIES	34		3179.0000	3179.0000	.0000	.0000	(1)
SPECIES	35		3179.0000	3179.0000	.0000	.0000	(1)
SPECIES	37		3179.0000	3179.0000	.0000	.0000	(1)
LOCATION	3	NEAR CLARKSDALE	286121.0000	15895.6111	18213.7994	************	(18)
SPECIES	2		50866.0000	50866.0000	.0000	.0000	(1)
SPECIES	4		9538.0000	9538.0000	.0000	.0000	(1)
SPECIES	6		3179.0000	3179.0000	.0000	.0000	(1)
SPECIES	7		3179.0000	3179.0000	.0000	.0000	(1)
SPECIES	8		12717.0000	12717.0000	.0000	.0000	(1)
SPECIES	10		60403.0000	60403.0000	.0000	.0000	(1)
SPECIES	12		3179.0000	3179.0000	.0000	.0000	(1)
SPECIES	14		28612.0000	28612.0000	.0000	.0000	(1)
SPECIES	15		3179.0000	3179.0000	.0000	.0000	(1)
SPECIES	22		3179.0000	3179.0000	.0000	.0000	(1)
SPECIES	23		19075.0000	19075.0000	.0000	.0000	(1)
SPECIES	28		6358.0000	6358.0000	.0000	.0000	(1)
SPECIES	29		41329.0000	41329.0000	.0000	.0000	(1)
SPECIES	31		3179.0000	3179.0000	.0000	.0000	(1)
SPECIES	33		25433.0000	25433.0000	.0000	.0000	(1)
SPECIES	34		3179.0000	3179.0000	.0000	.0000	(1)
SPECIES	37		6358.0000	6358.0000	.0000	.0000	(1)
SPECIES	38		3179.0000	3179.0000	.0000	.0000	(1)
LOCATION	[illegible]	BITTER CR.	30951.0000	2579.2500	3421.9548	11[illegible].3864	([illegible])
SPECIES	1		785.0000	785.0000	.0000	.0000	(1)
SPECIES	2		1588.0000	1588.0000	.0000	.0000	(1)
SPECIES	[illegible]		793.0000	793.0000	.0000	.0000	(1)
SPECIES	10		3177.0000	3177.0000	.0000	.0000	(1)
SPECIES	11		793.0000	793.0000	.0000	.0000	(1)
SPECIES	17		793.0000	793.0000	.0000	.0000	(1)
SPECIES	22		1589.0000	1589.0000	.0000	.0000	(1)
SPECIES	25		793.0000	793.0000	.0000	.0000	(1)
SPECIES	28		12704.0000	12704.0000	.0000	.0000	(1)
SPECIES	29		4762.0000	4762.0000	.0000	.0000	(1)
SPECIES	32		793.0000	793.0000	.0000	.0000	(1)
SPECIES	37		2381.0000	2381.0000	.0000	.0000	(1)
DATE	2	06-27-80	3526265.0000	58771.0833	117433.3293	************	(60)
LOCATION	1	ABOVE BITTER CR.	497250.0000	29250.0000	35568.0751	************	(17)
SPECIES	1		4076.0000	4076.0000	.0000	.0000	(1)
SPECIES	2		81516.0000	81516.0000	.0000	.0000	(1)
SPECIES	4		4076.0000	4076.0000	.0000	.0000	(1)
SPECIES	6		28531.0000	28531.0000	.0000	.0000	(1)
SPECIES	7		69289.0000	69289.0000	.0000	.0000	(1)
SPECIES	11		16303.0000	16303.0000	.0000	.0000	(1)
SPECIES	12		110047.0000	110047.0000	.0000	.0000	(1)
SPECIES	13		4076.0000	4076.0000	.0000	.0000	(1)
SPECIES	14		77440.0000	77440.0000	.0000	.0000	(1)
SPECIES	18		4076.0000	4076.0000	.0000	.0000	(1)
SPECIES	23		16303.0000	16303.0000	.0000	.0000	(1)
SPECIES	24		4076.0000	4076.0000	.0000	.0000	(1)
SPECIES	29		4076.0000	4076.0000	.0000	.0000	(1)
SPECIES	30		4076.0000	4076.0000	.0000	.0000	(1)
SPECIES	33		4076.0000	4076.0000	.0000	.0000	(1)
SPECIES	34		4076.0000	4076.0000	.0000	.0000	(1)
SPECIES	37		61137.0000	61137.0000	.0000	.0000	(1)

[5] See Appendix One for specific names of genera and species reported here by code.

Table 10. Con't.

LOCATION	2	BELOW BITTER CR.	1283682.0000	64184.1000	175386.8[illegible]67	************	(20)
SPECIES	1		218.0000	218.0000	.0000	.0000	(1)
SPECIES	2		794780.0000	794780.0000	.0000	.0000	(1)
SPECIES	4		218.0000	218.0000	.0000	.0000	(1)
SPECIES	6		58873.0000	58873.0000	.0000	.0000	(1)
SPECIES	7		17662.0000	17662.0000	.0000	.0000	(1)
SPECIES	8		218.0000	218.0000	.0000	.0000	(1)
SPECIES	10		117745.0000	117745.0000	.0000	.0000	(1)
SPECIES	13		218.0000	218.0000	.0000	.0000	(1)
SPECIES	14		105971.0000	105971.0000	.0000	.0000	(1)
SPECIES	15		218.0000	218.0000	.0000	.0000	(1)
SPECIES	19		218.0000	218.0000	.0000	.0000	(1)
SPECIES	22		35320.0000	35320.0000	.0000	.0000	(1)
SPECIES	23		23526.0000	23526.0000	.0000	.0000	(1)
SPECIES	24		218.0000	218.0000	.0000	.0000	(1)
SPECIES	25		11763.0000	11763.0000	.0000	.0000	(1)
SPECIES	27		218.0000	218.0000	.0000	.0000	(1)
SPECIES	29		11763.0000	11763.0000	.0000	.0000	(1)
SPECIES	31		17662.0000	17662.0000	.0000	.0000	(1)
SPECIES	33		35320.0000	35320.0000	.0000	.0000	(1)
SPECIES	37		51553.0000	51553.0000	.0000	.0000	(1)
LOCATION	3	NEAR CLARKSDALE	1745333.0000	75884.0435	92150.0574	************	(23)
SPECIES	1		6358.0000	6358.0000	.0000	.0000	(1)
SPECIES	2		317912.0000	317912.0000	.0000	.0000	(1)
SPECIES	4		6358.0000	6358.0000	.0000	.0000	(1)
SPECIES	6		50866.0000	50866.0000	.0000	.0000	(1)
SPECIES	7		19074.0000	19074.0000	.0000	.0000	(1)
SPECIES	8		57224.0000	57224.0000	.0000	.0000	(1)
SPECIES	10		254330.0000	254330.0000	.0000	.0000	(1)
SPECIES	11		6358.0000	6358.0000	.0000	.0000	(1)
SPECIES	13		50866.0000	50866.0000	.0000	.0000	(1)
SPECIES	14		190747.0000	190747.0000	.0000	.0000	(1)
SPECIES	17		19074.0000	19074.0000	.0000	.0000	(1)
SPECIES	22		50865.0000	50865.0000	.0000	.0000	(1)
SPECIES	23		82657.0000	82657.0000	.0000	.0000	(1)
SPECIES	24		7948.0000	7948.0000	.0000	.0000	(1)
SPECIES	25		6358.0000	6358.0000	.0000	.0000	(1)
SPECIES	28		7948.0000	7948.0000	.0000	.0000	(1)
SPECIES	29		19074.0000	19074.0000	.0000	.0000	(1)
SPECIES	31		44508.0000	44508.0000	.0000	.0000	(1)
SPECIES	33		228897.0000	228897.0000	.0000	.0000	(1)
SPECIES	34		6358.0000	6358.0000	.0000	.0000	(1)
SPECIES	35		133523.0000	133523.0000	.0000	.0000	(1)
SPECIES	36		19074.0000	19074.0000	.0000	.0000	(1)
SPECIES	37		158956.0000	158956.0000	.0000	.0000	(1)

DATE	3	08-30-80	2753236.0000	30591.5111	61757.3769	************	(90)
LOCATION	2	BELOW BITTER CR.	806514.0000	33604.7500	46859.9116	************	(24)
SPECIES	1		13623.0000	13623.0000	.0000	.0000	(1)
SPECIES	2		181210.0000	181210.0000	.0000	.0000	(1)
SPECIES	6		18121.0000	18121.0000	.0000	.0000	(1)
SPECIES	7		9060.0000	9060.0000	.0000	.0000	(1)
SPECIES	9		18121.0000	18121.0000	.0000	.0000	(1)
SPECIES	10		13623.0000	13623.0000	.0000	.0000	(1)
SPECIES	12		9060.0000	9060.0000	.0000	.0000	(1)
SPECIES	14		22571.0000	22571.0000	.0000	.0000	(1)
SPECIES	15		18121.0000	18121.0000	.0000	.0000	(1)
SPECIES	20		4451.0000	4451.0000	.0000	.0000	(1)
SPECIES	21		4451.0000	4451.0000	.0000	.0000	(1)
SPECIES	22		108885.0000	108885.0000	.0000	.0000	(1)
SPECIES	23		4451.0000	4451.0000	.0000	.0000	(1)
SPECIES	24		4451.0000	4451.0000	.0000	.0000	(1)
SPECIES	25		4451.0000	4451.0000	.0000	.0000	(1)
SPECIES	27		27182.0000	27182.0000	.0000	.0000	(1)
SPECIES	30		13623.0000	13623.0000	.0000	.0000	(1)
SPECIES	31		36242.0000	36242.0000	.0000	.0000	(1)
SPECIES	32		45303.0000	45303.0000	.0000	.0000	(1)
SPECIES	33		18121.0000	18121.0000	.0000	.0000	(1)
SPECIES	34		9060.0000	9060.0000	.0000	.0000	(1)
SPECIES	35		13623.0000	13623.0000	.0000	.0000	(1)
SPECIES	37		58973.0000	58973.0000	.0000	.0000	(1)
SPECIES	38		149737.0000	149737.0000	.0000	.0000	(1)

Table 10. Con't.

LOCATION	3	NEAR CLARKSDALE	1422671.0000	59277.9583	102222.9061	************	(	24)
SPECIES	1		26482.0000	26482.0000	.0000	.0000	(	1)
SPECIES	2		139087.0000	139087.0000	.0000	.0000	(	1)
SPECIES	3		6613.0000	6613.0000	.0000	.0000	(	1)
SPECIES	6		46256.0000	46256.0000	.0000	.0000	(	1)
SPECIES	7		6613.0000	6613.0000	.0000	.0000	(	1)
SPECIES	8		39739.0000	39739.0000	.0000	.0000	(	1)
SPECIES	9		6613.0000	6613.0000	.0000	.0000	(	1)
SPECIES	10		19870.0000	19870.0000	.0000	.0000	(	1)
SPECIES	11		13246.0000	13246.0000	.0000	.0000	(	1)
SPECIES	12		6613.0000	6613.0000	.0000	.0000	(	1)
SPECIES	13		6613.0000	6613.0000	.0000	.0000	(	1)
SPECIES	14		26482.0000	26482.0000	.0000	.0000	(	1)
SPECIES	15		33062.0000	33062.0000	.0000	.0000	(	1)
SPECIES	18		6613.0000	6613.0000	.0000	.0000	(	1)
SPECIES	22		99189.0000	99189.0000	.0000	.0000	(	1)
SPECIES	24		13246.0000	13246.0000	.0000	.0000	(	1)
SPECIES	29		6613.0000	6613.0000	.0000	.0000	(	1)
SPECIES	30		6613.0000	6613.0000	.0000	.0000	(	1)
SPECIES	31		13246.0000	13246.0000	.0000	.0000	(	1)
SPECIES	33		13246.0000	13246.0000	.0000	.0000	(	1)
SPECIES	34		416465.0000	416465.0000	.0000	.0000	(	1)
SPECIES	35		46368.0000	46368.0000	.0000	.0000	(	1)
SPECIES	37		105971.0000	105971.0000	.0000	.0000	(	1)
SPECIES	38		317812.0000	317812.0000	.0000	.0000	(	1)

LOCATION	4	1A	176444.0000	9286.5263	9257.4281	85699974.8187	(	19)
SPECIES	2		19075.0000	19075.0000	.0000	.0000	(	1)
SPECIES	3		3179.0000	3179.0000	.0000	.0000	(	1)
SPECIES	7		14306.0000	14306.0000	.0000	.0000	(	1)
SPECIES	9		1590.0000	1590.0000	.0000	.0000	(	1)
SPECIES	10		1590.0000	1590.0000	.0000	.0000	(	1)
SPECIES	11		1590.0000	1590.0000	.0000	.0000	(	1)
SPECIES	14		15896.0000	15896.0000	.0000	.0000	(	1)
SPECIES	15		25433.0000	25433.0000	.0000	.0000	(	1)
SPECIES	21		1590.0000	1590.0000	.0000	.0000	(	1)
SPECIES	22		6358.0000	6358.0000	.0000	.0000	(	1)
SPECIES	23		1590.0000	1590.0000	.0000	.0000	(	1)
SPECIES	25		3179.0000	3179.0000	.0000	.0000	(	1)
SPECIES	29		7948.0000	7948.0000	.0000	.0000	(	1)
SPECIES	30		33381.0000	33381.0000	.0000	.0000	(	1)
SPECIES	31		17485.0000	17485.0000	.0000	.0000	(	1)
SPECIES	32		1590.0000	1590.0000	.0000	.0000	(	1)
SPECIES	33		6358.0000	6358.0000	.0000	.0000	(	1)
SPECIES	34		4769.0000	4769.0000	.0000	.0000	(	1)
SPECIES	37		9537.0000	9537.0000	.0000	.0000	(	1)
LOCATION	5	1B	347607.0000	15113.3478	24266.8045	*************	(	23)
SPECIES	1		5298.0000	5298.0000	.0000	.0000	(	1)
SPECIES	2		33381.0000	33381.0000	.0000	.0000	(	1)
SPECIES	3		17485.0000	17485.0000	.0000	.0000	(	1)
SPECIES	4		5298.0000	5298.0000	.0000	.0000	(	1)
SPECIES	6		5298.0000	5298.0000	.0000	.0000	(	1)
SPECIES	7		10602.0000	10602.0000	.0000	.0000	(	1)
SPECIES	8		15896.0000	15896.0000	.0000	.0000	(	1)
SPECIES	9		5298.0000	5298.0000	.0000	.0000	(	1)
SPECIES	10		10602.0000	10602.0000	.0000	.0000	(	1)
SPECIES	12		5298.0000	5298.0000	.0000	.0000	(	1)
SPECIES	14		5298.0000	5298.0000	.0000	.0000	(	1)
SPECIES	20		5298.0000	5298.0000	.0000	.0000	(	1)
SPECIES	22		21194.0000	21194.0000	.0000	.0000	(	1)
SPECIES	25		5298.0000	5298.0000	.0000	.0000	(	1)
SPECIES	28		5298.0000	5298.0000	.0000	.0000	(	1)
SPECIES	29		10602.0000	10602.0000	.0000	.0000	(	1)
SPECIES	30		5298.0000	5298.0000	.0000	.0000	(	1)
SPECIES	31		10602.0000	10602.0000	.0000	.0000	(	1)
SPECIES	32		15896.0000	15896.0000	.0000	.0000	(	1)
SPECIES	33		5298.0000	5298.0000	.0000	.0000	(	1)
SPECIES	34		10602.0000	10602.0000	.0000	.0000	(	1)
SPECIES	37		10602.0000	10602.0000	.0000	.0000	(	1)
SPECIES	38		121865.0000	121865.0000	.0000	.0000	(	1)

Table 10. Con't.

DATE	4	10-23-80	3210131.0000	56318.0877	106871.0282	*************	(57)
LOCATION	2	BELOW BITTER CR.	1128521.0000	62695.6111	168943.2785	*************	(18)
SPECIES	1		6342.0000	6342.0000	.0000	.0000	(1)
SPECIES	2		731039.0000	731039.0000	.0000	.0000	(1)
SPECIES	4		6342.0000	6342.0000	.0000	.0000	(1)
SPECIES	9		6342.0000	6342.0000	.0000	.0000	(1)
SPECIES	10		22890.0000	22890.0000	.0000	.0000	(1)
SPECIES	13		12684.0000	12684.0000	.0000	.0000	(1)
SPECIES	14		50548.0000	50548.0000	.0000	.0000	(1)
SPECIES	15		69909.0000	69909.0000	.0000	.0000	(1)
SPECIES	23		6342.0000	6342.0000	.0000	.0000	(1)
SPECIES	28		6342.0000	6342.0000	.0000	.0000	(1)
SPECIES	29		25417.0000	25417.0000	.0000	.0000	(1)
SPECIES	30		6358.0000	6358.0000	.0000	.0000	(1)
SPECIES	31		6342.0000	6342.0000	.0000	.0000	(1)
SPECIES	32		6342.0000	6342.0000	.0000	.0000	(1)
SPECIES	34		6342.0000	6342.0000	.0000	.0000	(1)
SPECIES	35		57224.0000	57224.0000	.0000	.0000	(1)
SPECIES	37		6342.0000	6342.0000	.0000	.0000	(1)
SPECIES	38		95374.0000	95374.0000	.0000	.0000	(1)
LOCATION	3	NEAR CLARKSDALE	804426.0000	33517.7500	36467.9338	*************	(24)
SPECIES	1		6676.0000	6676.0000	.0000	.0000	(1)
SPECIES	2		107438.0000	107438.0000	.0000	.0000	(1)
SPECIES	3		13352.0000	13352.0000	.0000	.0000	(1)
SPECIES	4		6676.0000	6676.0000	.0000	.0000	(1)
SPECIES	6		13352.0000	13352.0000	.0000	.0000	(1)
SPECIES	7		6676.0000	6676.0000	.0000	.0000	(1)
SPECIES	10		46972.0000	46972.0000	.0000	.0000	(1)
SPECIES	12		6676.0000	6676.0000	.0000	.0000	(1)
SPECIES	13		6676.0000	6676.0000	.0000	.0000	(1)
SPECIES	14		46972.0000	46972.0000	.0000	.0000	(1)
SPECIES	15		80591.0000	80591.0000	.0000	.0000	(1)
SPECIES	22		20124.0000	20124.0000	.0000	.0000	(1)
SPECIES	23		67143.0000	67143.0000	.0000	.0000	(1)
SPECIES	24		6676.0000	6676.0000	.0000	.0000	(1)
SPECIES	25		6676.0000	6676.0000	.0000	.0000	(1)
SPECIES	26		6676.0000	6676.0000	.0000	.0000	(1)
SPECIES	29		33380.0000	33380.0000	.0000	.0000	(1)
SPECIES	30		26848.0000	26848.0000	.0000	.0000	(1)
SPECIES	32		6676.0000	6676.0000	.0000	.0000	(1)
SPECIES	33		13352.0000	13352.0000	.0000	.0000	(1)
SPECIES	34		147734.0000	147734.0000	.0000	.0000	(1)
SPECIES	35		53409.0000	53409.0000	.0000	.0000	(1)
SPECIES	37		33380.0000	33380.0000	.0000	.0000	(1)
SPECIES	36		40295.0000	40295.0000	.0000	.0000	(1)
LOCATION	4	1A	1277184.0000	85145.6000	83719.8745	*************	(15)
SPECIES	2		267048.0000	267048.0000	.0000	.0000	(1)
SPECIES	6		12684.0000	12684.0000	.0000	.0000	(1)
SPECIES	7		50862.0000	50862.0000	.0000	.0000	(1)
SPECIES	8		6198.0000	6198.0000	.0000	.0000	(1)
SPECIES	10		235239.0000	235239.0000	.0000	.0000	(1)
SPECIES	13		25416.0000	25416.0000	.0000	.0000	(1)
SPECIES	14		184386.0000	184386.0000	.0000	.0000	(1)
SPECIES	22		44493.0000	44493.0000	.0000	.0000	(1)
SPECIES	23		88983.0000	88983.0000	.0000	.0000	(1)
SPECIES	29		50862.0000	50862.0000	.0000	.0000	(1)
SPECIES	30		95373.0000	95373.0000	.0000	.0000	(1)
SPECIES	31		69624.0000	69624.0000	.0000	.0000	(1)
SPECIES	33		12684.0000	12684.0000	.0000	.0000	(1)
SPECIES	34		6198.0000	6198.0000	.0000	.0000	(1)
SPECIES	38		127134.0000	127134.0000	.0000	.0000	(1)

TOTAL CASES = 253

Table 11. Diatom genera[6] totals by location and date with descriptive statistics.

VARIABLE	CODE	VALUE LABEL	SUM	MEAN	STD DEV	VARIANCE	N
FOR ENTIRE POPULATION			10137069.0000	40067.4664	87505.3738	*************	(253)
DATE	1	05-28-80	647437.0000	14074.7174	37035.1370	*************	(46)
LOCATION	1	ABOVE BITTER CR.	330365.0000	20647.8125	59786.7943	*************	(16)
GENUS	4		6358.0000	6358.0000	.0000	.0000	(1)
GENUS	6		9537.0000	4768.5000	2247.8925	5053020.5000	(2)
GENUS	7		9524.0000	9524.0000	.0000	.0000	(1)
GENUS	9		247723.0000	123861.5000	170670.8282	*************	(2)
GENUS	10		3179.0000	3179.0000	.0000	.0000	(1)
GENUS	11		3179.0000	3179.0000	.0000	.0000	(1)
GENUS	16		19075.0000	9537.5000	4496.4920	20218440.5000	(2)
GENUS	18		22253.0000	7417.6667	3670.7930	13474721.3333	(3)
GENUS	19		3179.0000	3179.0000	.0000	.0000	(1)
GENUS	20		3179.0000	3179.0000	.0000	.0000	(1)
GENUS	21		3179.0000	3179.0000	.0000	.0000	(1)
LOCATION	3	NEAR CLARKSDALE	286121.0000	15895.6111	18213.7994	*************	(18)
GENUS	1		50866.0000	50866.0000	.0000	.0000	(1)
GENUS	4		9538.0000	9538.0000	.0000	.0000	(1)
GENUS	6		6358.0000	3179.0000	.0000	.0000	(2)
GENUS	7		12717.0000	12717.0000	.0000	.0000	(1)
GENUS	9		63582.0000	31791.0000	40463.4784	*************	(2)
GENUS	11		28612.0000	28612.0000	.0000	.0000	(1)
GENUS	12		3179.0000	3179.0000	.0000	.0000	(1)
GENUS	16		22254.0000	11127.0000	11240.1694	*************	(2)
GENUS	18		76299.0000	19074.7500	17795.7821	*************	(4)
GENUS	19		3179.0000	3179.0000	.0000	.0000	(1)
GENUS	21		9537.0000	4768.5000	2247.8925	5053020.5000	(2)
LOCATION	6	BITTER CR.	30951.0000	2579.2500	3421.9548	11709774.3864	(12)
GENUS	1		2373.0000	1186.5000	567.8067	322404.5000	(2)
GENUS	6		793.0000	793.0000	.0000	.0000	(1)
GENUS	9		3970.0000	1985.0000	1685.7426	2841728.0000	(2)
GENUS	13		793.0000	793.0000	.0000	.0000	(1)
GENUS	16		2382.0000	1191.0000	562.8570	316808.0000	(2)
GENUS	18		18259.0000	6086.3333	6064.9299	36783374.3333	(3)
GENUS	21		2381.0000	2381.0000	.0000	.0000	(1)
DATE	2	06-27-80	3526265.0000	58771.0833	117433.3293	*************	(60)
LOCATION	1	ABOVE BITTER CR.	497250.0000	29250.0000	33568.0751	*************	(17)
GENUS	1		85592.0000	42796.0000	54758.3491	*************	(2)
GENUS	4		4076.0000	4076.0000	.0000	.0000	(1)
GENUS	6		97820.0000	48910.0000	28820.2582	*************	(2)
GENUS	9		126350.0000	63175.0000	66287.0181	*************	(2)
GENUS	10		4076.0000	4076.0000	.0000	.0000	(1)
GENUS	11		77440.0000	77440.0000	.0000	.0000	(1)
GENUS	13		4076.0000	4076.0000	.0000	.0000	(1)
GENUS	16		20379.0000	10189.5000	8645.7946	74749764.5000	(2)
GENUS	18		12228.0000	4076.0000	.0000	.0000	(3)
GENUS	19		4076.0000	4076.0000	.0000	.0000	(1)
GENUS	21		61137.0000	61137.0000	.0000	.0000	(1)
LOCATION	2	BELOW BITTER CR.	1283682.0000	64184.1000	175386.8267	*************	(20)
GENUS	1		794998.0000	397499.0000	561840.1783	*************	(2)
GENUS	4		218.0000	218.0000	.0000	.0000	(1)
GENUS	6		76535.0000	38267.5000	29140.5776	*************	(2)
GENUS	7		218.0000	218.0000	.0000	.0000	(1)
GENUS	9		117745.0000	117745.0000	.0000	.0000	(1)
GENUS	10		218.0000	218.0000	.0000	.0000	(1)
GENUS	11		105971.0000	105971.0000	.0000	.0000	(1)
GENUS	12		218.0000	218.0000	.0000	.0000	(1)
GENUS	13		218.0000	218.0000	.0000	.0000	(1)
GENUS	16		70827.0000	17706.7500	15113.7331	*************	(4)
GENUS	17		218.0000	218.0000	.0000	.0000	(1)
GENUS	18		64745.0000	21581.6667	12257.8914	*************	(3)
GENUS	21		51553.0000	51553.0000	.0000	.0000	(1)

[6] See Appendix One for specific names of genera and species reported here by code.

Table 11. Con't.

LOCATION	3	NEAR CLARKSDALE	1745333.0000	75884.0435	92150.0574	*************	(	23)
GENUS	1		324270.0000	162135.0000	220301.9461	*************	(	2)
GENUS	4		6358.0000	6358.0000	.0000	.0000	(	1)
GENUS	6		69940.0000	34970.0000	22480.3388	*************	(	2)
GENUS	7		57224.0000	57224.0000	.0000	.0000	(	1)
GENUS	9		260688.0000	130344.0000	175342.6827	*************	(	2)
GENUS	10		50866.0000	50866.0000	.0000	.0000	(	1)
GENUS	11		190747.0000	190747.0000	.0000	.0000	(	1)
GENUS	13		19074.0000	19074.0000	.0000	.0000	(	1)
GENUS	16		147828.0000	36957.0000	36786.5163	*************	(	4)
GENUS	18		300427.0000	75106.7500	103662.4189	*************	(	4)
GENUS	19		6358.0000	6358.0000	.0000	.0000	(	1)
GENUS	20		133523.0000	133523.0000	.0000	.0000	(	1)
GENUS	21		178030.0000	89015.0000	98911.5108	*************	(	2)
DATE	3	08-30-80	2753236.0000	30591.5111	61757.3769	*************	(	90)
LOCATION	2	BELOW BITTER CR.	806514.0000	33604.7500	46859.9116	*************	(	24)
GENUS	1		194833.0000	97416.5000	118501.9041	*************	(	2)
GENUS	6		27181.0000	13590.5000	6407.0945	41050860.5000	(	2)
GENUS	8		18121.0000	18121.0000	.0000	.0000	(	1)
GENUS	9		22683.0000	11341.5000	3226.5282	10410484.5000	(	2)
GENUS	11		22571.0000	22571.0000	.0000	.0000	(	1)
GENUS	12		18121.0000	18121.0000	.0000	.0000	(	1)
GENUS	14		4451.0000	4451.0000	.0000	.0000	(	1)
GENUS	15		4451.0000	4451.0000	.0000	.0000	(	1)
GENUS	16		122238.0000	30559.5000	52217.0000	*************	(	4)
GENUS	18		140471.0000	28094.2000	12963.8140	*************	(	5)
GENUS	19		9060.0000	9060.0000	.0000	.0000	(	1)
GENUS	20		13623.0000	13623.0000	.0000	.0000	(	1)
GENUS	21		208710.0000	104355.0000	64179.8399	*************	(	2)
LOCATION	3	NEAR CLARKSDALE	1422671.0000	59277.9583	102222.9061	*************	(	24)
GENUS	1		165569.0000	82784.5000	79623.7591	*************	(	2)
GENUS	2		6613.0000	6613.0000	.0000	.0000	(	1)
GENUS	6		52869.0000	26434.5000	28031.8341	*************	(	2)
GENUS	7		39739.0000	39739.0000	.0000	.0000	(	1)
GENUS	8		6613.0000	6613.0000	.0000	.0000	(	1)
GENUS	9		39729.0000	13243.0000	6628.5005	43937019.0000	(	3)
GENUS	10		6613.0000	6613.0000	.0000	.0000	(	1)
GENUS	11		26482.0000	26482.0000	.0000	.0000	(	1)
GENUS	12		33062.0000	33062.0000	.0000	.0000	(	1)
GENUS	13		6613.0000	6613.0000	.0000	.0000	(	1)
GENUS	16		112435.0000	56217.5000	60770.8781	*************	(	2)
GENUS	18		39718.0000	9929.5000	3829.5643	14665563.0000	(	4)
GENUS	19		416465.0000	416465.0000	.0000	.0000	(	1)
GENUS	20		46368.0000	46368.0000	.0000	.0000	(	1)
GENUS	21		423783.0000	211891.5000	149794.2076	*************	(	2)
LOCATION	4	1A	176444.0000	9286.5263	9257.4281	85699974.8187	(	19)
GENUS	1		19075.0000	19075.0000	.0000	.0000	(	1)
GENUS	2		3179.0000	3179.0000	.0000	.0000	(	1)
GENUS	6		14306.0000	14306.0000	.0000	.0000	(	1)
GENUS	8		1590.0000	1590.0000	.0000	.0000	(	1)
GENUS	9		3180.0000	1590.0000	.0000	.0000	(	2)
GENUS	11		15896.0000	15896.0000	.0000	.0000	(	1)
GENUS	12		25433.0000	25433.0000	.0000	.0000	(	1)
GENUS	15		1590.0000	1590.0000	.0000	.0000	(	1)
GENUS	16		11127.0000	3709.0000	2427.7831	5894131.0000	(	3)
GENUS	18		66762.0000	13352.4000	12596.6903	*************	(	5)
GENUS	19		4769.0000	4769.0000	.0000	.0000	(	1)
GENUS	21		9537.0000	9537.0000	.0000	.0000	(	1)

Table 11. Con't.

LOCATION	5	1B	347607.0000	15113.3478	24266.8045	*************	(23)
GENUS	1		38679.0000	19339.5000	19857.6797	*************	(2)
GENUS	2		17485.0000	17485.0000	.0000	.0000	(1)
GENUS	4		5298.0000	5298.0000	.0000	.0000	(1)
GENUS	6		15900.0000	7950.0000	3750.4944	14066208.0000	(2)
GENUS	7		15896.0000	15896.0000	.0000	.0000	(1)
GENUS	8		5298.0000	5298.0000	.0000	.0000	(1)
GENUS	9		15900.0000	7950.0000	3750.4944	14066208.0000	(2)
GENUS	11		5298.0000	5298.0000	.0000	.0000	(1)
GENUS	14		5298.0000	5298.0000	.0000	.0000	(1)
GENUS	16		26492.0000	13246.0000	11240.1694	*************	(2)
GENUS	17		5298.0000	5298.0000	.0000	.0000	(1)
GENUS	18		47696.0000	9539.2000	4434.0599	19660887.2000	(5)
GENUS	19		10602.0000	10602.0000	.0000	.0000	(1)
GENUS	21		132467.0000	66233.5000	78674.8218	*************	(2)
DATE	4	10-23-80	3210131.0000	56318.0877	106871.0282	*************	(57)
LOCATION	2	BELOW BITTER CR.	1128521.0000	62695.6111	168943.2785	*************	(18)
GENUS	1		737381.0000	368690.5000	512438.1630	*************	(2)
GENUS	4		6342.0000	6342.0000	.0000	.0000	(1)
GENUS	8		6342.0000	6342.0000	.0000	.0000	(1)
GENUS	9		22890.0000	22890.0000	.0000	.0000	(1)
GENUS	10		12684.0000	12684.0000	.0000	.0000	(1)
GENUS	11		50548.0000	50548.0000	.0000	.0000	(1)
GENUS	12		69909.0000	69909.0000	.0000	.0000	(1)
GENUS	16		6342.0000	6342.0000	.0000	.0000	(1)
GENUS	18		50801.0000	10160.2000	8528.8133	72740656.2000	(5)
GENUS	19		6342.0000	6342.0000	.0000	.0000	(1)
GENUS	20		57224.0000	57224.0000	.0000	.0000	(1)
GENUS	21		101716.0000	50858.0000	62955.1309	*************	(2)
LOCATION	3	NEAR CLARKSDALE	804426.0000	33517.7500	36467.9338	*************	(24)
GENUS	1		114114.0000	57057.0000	71249.4935	*************	(2)
GENUS	3		13352.0000	13352.0000	.0000	.0000	(1)
GENUS	4		6676.0000	6676.0000	.0000	.0000	(1)
GENUS	6		20028.0000	10014.0000	4720.6449	22284408.0000	(2)
GENUS	9		53648.0000	26824.0000	28493.5749	*************	(2)
GENUS	10		6676.0000	6676.0000	.0000	.0000	(1)
GENUS	11		46972.0000	46972.0000	.0000	.0000	(1)
GENUS	12		80591.0000	80591.0000	.0000	.0000	(1)
GENUS	16		100619.0000	25154.7500	28701.0452	*************	(4)
GENUS	17		6676.0000	6676.0000	.0000	.0000	(1)
GENUS	18		80256.0000	20064.0000	12215.1272	*************	(4)
GENUS	19		147734.0000	147734.0000	.0000	.0000	(1)
GENUS	20		53409.0000	53409.0000	.0000	.0000	(1)
GENUS	21		73675.0000	36837.5000	4889.6434	23908612.5000	(2)
LOCATION	4	1A	1277184.0000	85145.6000	83719.0745	*************	(15)
GENUS	1		267048.0000	267048.0000	.0000	.0000	(1)
GENUS	6		63546.0000	31773.0000	26995.9227	*************	(2)
GENUS	7		6198.0000	6198.0000	.0000	.0000	(1)
GENUS	9		235239.0000	235239.0000	.0000	.0000	(1)
GENUS	10		25416.0000	25416.0000	.0000	.0000	(1)
GENUS	11		184386.0000	184386.0000	.0000	.0000	(1)
GENUS	16		133476.0000	66738.0000	31459.1807	*************	(2)
GENUS	18		228543.0000	57135.7500	34801.1575	*************	(4)
GENUS	19		6198.0000	6198.0000	.0000	.0000	(1)
GENUS	21		127134.0000	127134.0000	.0000	.0000	(1)

TOTAL CASES = 253

Copper concentration did not vary by sample location so correlations were not attempted. Location was correlated with zinc concentrations and with primary productivity using the (non-parametric) Spearman's rho test. This statistic compares variable pairs solely on the basis of rank. In this case the sampling sites were ranked as follows:

1. Bitter Creek proper. (BC)
2. Verde River, immediately (10 m) below confluence of Bitter Creek and Verde River. (S_2)
3. Verde River, approximately 150 m below the confluence of Bitter Creek and Verde River. (S_3)
4. Verde River, near Clarkdale Sewage Treatment Facility. (S_4)
5. Verde River, above Bitter Creek-Verde River confluence. (S_1)

Using this test, correlations were highly significant in both cases, as:

location-zinc	location-primary productivity
rho = 0.94	rho = 0.83

CONCLUSIONS

Carbon-14 uptake measurements were successfully completed *in situ* with light-dark chambers under simulated current conditions. Values for periphyton primary productivity were commonly 50-70% lower immediately below the confluence of Bitter Creek and the Verde River than above the confluence. The values were slightly lower (15-25%) at about 150 m below the confluence than immediately above it. Periphyton productivity was about the same near the Clarkdale Sewage Treatment Facility as it was about 2 km upstream above the confluence of the Verde River and Bitter Creek.

Heavy metals thought to be biologically problematic (Zn, Cu, Fe) were monitored: Zn concentrations in Bitter Creek decreased dramatically (10-fold or more) upon dilution with Verde River. Copper concentrations were uniformally low, as were iron concentrations.

Periphyton collections made at Slide Rock appear similar as all respects to those made one year earlier and reported in Avery and Blinn (1981).

These results show a dramatic decrease in primary productivity below the confluence of Bitter Creek and the Verde River, and compositional changes in the microscopic algal periphyton community at several sites over a period of several months have been noted. Also, based on visual impressions, Cladophora was always the dominant filamentous green alga above the confluence, and Stigeoclonium was the apparent dominant filamentous green alga below the Bitter Creek-Verde River confluence.

Bitter Creek effluent does not appear to (statistically) impact the population structure or the total density (size) of the Verde River diatom community, and contrary to indications given by other reports, no single species appears to behave as a truly reliable "indicator" species. Yet effluent from Bitter Creek, especially zinc, does appear to suppress the primary productivity of the periphyton community. However, the zinc concentrations are rapidly diluted and it declines fairly rapidly below Bitter Creek.

It appears that sampling with more replication might have provided more definitive information than did the extensive sampling scheme that was employed to detect changes over several months.

Any form of a production function that is developed for a similar aquatic ecosystem should probably use primary productivity as the dependent variable. The use of a species abundance index or density values (counts), requires supplemental information, at least in these locations, to be inclusive.

At Slide Rock the periphyton community, once again, did not experience any apparent long-term shift over a summer period. As was stated by the authors in their 1981 report, "these data suggest that stream ecosystems are very resilient to heavy recreational use and that the biotic micro-components can assimilate intermittant (chemical loading) very rapidly and with no apparent modification in community structure."

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APPENDICES

Appendix 1. Density estimates of diatom species by dates and sites, May 28, 1980.

	Species	site 1	site 2	site 3	Bitter Creek
		cells/cm^2			
1.	*Achnanthes lanceolata* var. *dubia*			50866	785
2.	*Achnanthes microcephala/minutissima*				1588
3.	*Amphipleura pellucida*				
4.	*Amphora perpusilla*	6358		9538	
5.	*Caloneis amphisbaena*				
6.	*Cocconeis pediculus*	3179		3179	
7.	*Cocconeis placentula* var. *euglypta*	6358		3179	793
8.	*Cyclotella meneghiniana*	9524		12717	
9.	*Cymatopleura solea*				
10.	*Cymbella affinis*	244544		60403	3177
11.	*Cymbella sinuata*	3179			793
12.	*Cymbella tumida*			3179	
13.	*Diatoma vulgare*	3179			
14.	*Epithema sorex*	3179		28612	
15.	*Fragilaria leptostauron*			3179	
16.	*Fragilaria vaucheriae*				
17.	*Gomphonema olivaceum*				793
18.	*Gomphonema parvulum*				
19.	*Gomphonema ventricosum*				
20.	*Gyrosigma spencerii*				
21.	*Melosira varians*				
22.	*Navicula cryptocephala*	6358		3179	1589

Appendix 1. Cont'd. May 28, 1980.

	Species	site 1	site 2	site 3	Bitter Creek
		cells/cm^2			
23.	*Navicula cryptocephala* var. *veneta*	12717		19075	
24.	*Navicula decussis*				
25.	*Navicula pupula*				1625
26.	*Neduim affine*				
27.	*Neduim dubium* var. *constrictum*				
28.	*Nitzschia acicularis*			6358	12704
29.	*Nitzschia dissipata*	9537		41329	4762
30.	*Nitzschia fonticola*				
31.	*Nitzschia frustulum*	3179		3179	
32.	*Nitzschia microcephala*				793
33.	*Nitzschia palea*	9537		25433	
34.	*Rhopalodia gibba* var. *ventricosa*	3179		3179	
35.	*Surirella angustata*	3179			
36.	*Synedra acus*				
37.	*Synedra ulna*	3179		6358	2381
38.	*Synedra ulna* var. *oxyrhynchus* f. *mediocontracta*			3179	

Appendix 1. Cont'd. June 27, 1980.

Species	site 1	site 2	site 3	Bitter Creek
		cells/cm^2		
Achnanthes lanceolata var. *dubia*	4076	218	6358	
Achnanthes microcephala/ minutissima	81516	794780	317912	
Amphipleura pellucida				
Amphora perpusilla	4076	218	6358	
Caloneis amphisbaena				
Cocconeis pediculus	28531	5873	50866	
Cocconeis placentula var. *euglypta*	69289	17662	19074	
Cyclotella meneghiniana		218	57224	
Cymatopleura solea				
Cymbella affinis		117745	254330	
Cymbella sinuata	16303		6358	
Cymbella tumida	110047			
Diatoma vulgare	4076	218	50866	
Epithema sorex	77440	105971	190747	
Fragilaria leptostauron		218		
Fragilaria vaucheriae				
Gomphonema olivaceum			19074	
Gomphonema parvulum	4076			
Gomphonema ventricosum		218		
Gyrosigma spencerii				
Melosira varians				
Navicula cryptocephala		35320	50865	

Appendix 1. Cont'd. June 27, 1980.

Species	site 1	site 2	site 3	Bitter Creek
			cells/cm^2	
Navicula cryptocephala var. *veneta*	16303	23526	82657	
Navicula decussis	4076	218	7948	
Navicula pupula		11763	6358	
Neduim affine				
Neduim dubium var. *constrictum*		218		
Nitzschia acicularis			7948	
Nitzschia dissipata	4076	11763	19074	
Nitzschia fonticola	4076			
Nitzschia frustulum		17662	44508	
Nitzschia microcephala				
Nitzschia palea	4076	35320	228897	
Rhopalodia gibba var. *ventricosa*	4076		6358	
Surirella angustata			133523	
Synedra acus			19074	
Synedra ulna	61137	51553		
Synedra ulna var. *oxyrhynchus* f. *mediocontracta*			158956	

Appendix 1. Cont'd. August 30, 1980.

Species	site 1	site 2	site 3	Bitter Creek
		cells/cm^2		
Achnanthes lanceolata var. dubia		13623	26482	
Achnanthes microcephala/ minutissima		181210	139087	
Amphipleura pellucida			6613	
Amphora perpusilla				
Caloneis amphisbaena				
Cocconeis pediculus			46256	
Cocconeis placentula var. euglypta			6613	
Cyclotella meneghiniana			39739	
Cymatopleura solea			6613	
Cymbella affinis			19870	
Cymbella sinuata			13246	
Cymbella tumida			6613	
Diatoma vulgare			6613	
Epithema sorex			26482	
Fragilaria leptostauron			33062	
Fragilaria vaucheriae				
Gomphonema olivaceum				
Gomphonema parvulum				
Gomphonema ventricosum			6613	
Gyrosigma spencerii		4451		
Melosira varians		4451		
Navicula cryptocephala		108885	99189	

Appendix 1. Cont'd. August 30, 1980.

Species	site 1	site 2	site 3	Bitter Creek
		cells/cm^2		
Navicula cryptocephala var. *veneta*		4451		
Navicula decussis		4451	13246	
Navicula pupula		4451		
Neduim affine				
Neduim dubium var. *constrictum*				
Nitzschia acicularis				
Nitzschia dissipata		27182	6613	
Nitzschia fonticola		13623	6613	
Nitzschia frustulum		36242	13246	
Nitzschia microcephala		45303		
Nitzschia palea		18121	13246	
Rhopalodia gibba var. *ventricosa*		9060	416465	
Surirella angustata		13623	46368	
Synedra acus				
Synedra ulna		58973	105971	
Synedra ulna var. *oxyrhynchus* f. *mediocontracta*		149737	317812	

Appendix 1. Cont'd. October 23, 1980.

Species	site 1	site 2	site 3	Bitter Creek
		cells/cm^2		
Achnanthes lanceolata var. dubia		6342	6676	
Achnanthes microcephala/ minutissima		731039	107438	
Amphipleura pellucida			13352	
Amphora perpusilla		6342	6676	
Caloneis amphisbaena				
Cocconeis pediculus			13352	
Cocconeis placentula var. euglypta			6676	
Cyclotella meneghiniana				
Cymatopleura solea		6342		
Cymbella affinis		22890	46972	
Cymbella sinuata				
Cymbella tumida			6676	
Diatoma vulgare		12684		
Epithema sorex		50548	46972	
Fragilaria leptostauron		69969	80591	
Fragilaria vaucheriae				
Gomphonema olivaceum				
Gomphonema parvulum				
Gomphonema ventricosum				
Gyrosigma spencerii				
Melosira varians				
Navicula cryptocephala			20124	

Appendix 1. Cont'd. October 23, 1980.

Species	site 1	site 2	site 3	Bitter Creek
		cells/cm^2		
Navicula cryptocephala var. *veneta*		6342	67143	
Navicula decussis			6676	
Navicula pupula			6676	
Neduim affine			6676	
Neduim dubium var. *constrictum*				
Nitzschia acicularis		6342		
Nitzschia dissipata		25417	33380	
Nitzschia fonticola		6358	26848	
Nitzschia frustulum		6342		
Nitzschia microcephala		6342	6676	
Nitzschia palea			13352	
Rhopalodia gibba var. *ventricosa*		6342	147734	
Surirella angustata		57224	53409	
Synedra acus				
Synedra ulna		6342	33380	
Synedra ulna var. *oxyrhynchus* f. *mediocontracta*		95374	40295	

Appendix 2. Heavy metal (elemental) concentrations; Bitter Creek sites values reported in mg/l; BD = "below" detection limits.

Sample	Date 1980	Cu	Zn	Fe
BC	6/27	.20	5.15	3.85
Site 1A		BD	.01	BD
1B		BD	.83	.75
1C		BD	BD	BD
1D		BD	.02	BD
1E		.07	1.54	BD
Site 2		BD	.35	BD
2B		BD	.21	.01
Site 3		BD	.12	.14
BC	7/30	.20	6.90	3.22
Site 1A		BD	.28	BD
1B		BD	.06	BD
Site 2		BD	.19	BD
2B		BD	.14	BD
Site 3		BD	.39	BD
BC	8/30	BD	.75	.26
Site 1A		BD	.41	.21
Site 1		BD	.07	BD
Site 2		BD	.16	BD
2B		BD	.09	BD
Site 3		BD	.21	BD